International Journal of Agricultural
Science and Research (IJASR)
ISSN(P): 2250-0057; ISSN(E): 2321-0087
Vol. 5, Issue 3, Jun 2015, 243-258

DESIGN AND IMPLEMENTATION OF A WEB FRAMEWORK FOR DIGITAL IDENTIFICATION KEYS TO IDENTIFY FISHES

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ABSTRACT

Identification of biological organisms using digital methods has undoubtedly created interest among biologists. Recent developments in digital technologies, computer architecture and innovations in software design have facilitated techniques to address the challenging task of identification. The present communication discusses about a web framework implemented for identifying and browsing the information on fishes reported from Indian waters. The rationale for developing the digital framework was to automate the routine identification task for identifying specimens of previously described species. For developing the system, a relational database was developed for the morphometric measurement and meristic count characters to digitize and store the information on the characters measuring discreetness and relationships among fish species. These digitized characters were used as taxonomic digital keys for identification. A user friendly and interactive query system using the digital keys was developed to identify the fish specimen. Data on morphometric measurement, meristic counts, maximum size, common name, synonyms and distribution were compiled from the published literatures and web resources. The database presently contains information on morphometric characters taxonomy and distribution of 222 Indian fish species belonging to 12 families. The present system is an alternative method to easily and rapidly identify the specimen crossing the geography and ecosystem boundaries. It is much useful, versatile and scalable system even to identify the fish specimen during filed survey. It is expected that the developed system would be more useful resource for new researchers in fish systematics and for resolving taxonomy ambiguities.

KEYWORDS: Web Framework, Fish Identification System, Computer-Aided Fish Species Identification, Fish Species

INTRODUCTION

Among water-bodies, fishes are the most numerous and highly diversified group as they occupy different niches in various ecosystem and their morphological features and genetic makeup exhibit great variations. There are about 32,500 living species of fishes (Froese and Pauly, 2013), which makes very difficult their correct classification (Helfman et al., 2009). Fish species are traditionally identified based on external morphological characters (measurable structures such as fin length, head length, etc.), meristic characters (countable structures such as number of scales in the lateral line, number of vertebrae, etc.), anatomical characters of the skeleton and the soft anatomy or characters than include any fixed, describable differences among taxa such as color (presence of stripes, spots) photophores (number and position) and sexually dimorphic structures (Strauss et al., 1990; Bristow 1992; Helfman et al., 2009). An analysis of morphometric and

meristic characters has widely been used by the ichthyologists to differentiate between different species and among different populations within a species (Rohlf, 1990; Rohlf and Marcus, 1993; Foote, 1997; Cadrin, 2000; Wainwright, 2007). For this reason, meristic counts and morphometric measurements are the powerful tools for measuring discreteness and relationships among fish species (Guisande C. et. al. 2010). Precise fish identification requires that relevant information on the morphological, pigmentation, and color characteristics of each species should be presented in an understandable way, which would not only help in assessing the biodiversity but also developing conservation strategies to facilitate management and sustainable use of resources. Thus, the correct species identification is the basic starting point for any type of biological study, particularly one on wild populations (Rainboth, 1996).

Identification is a basic activity that involves both classification and nomenclature. It simply determines the similarities or differences between two elements being under systematics. In order to identify fish using the distinguishing characters as taxonomic keys, the user has to pass through a series of questions and illustrations that eventually lead him to the species matching the best characteristics. either of the categories of keys printed or electronic keys are commonly used for identification. Traditionally, the information about fish species for identification is available in books (Kaspiris, 2000; Whitehead et al., 1984; Fischer etal., 1987; Perlmutter, 1961; Fischer et al., 1981; Carpenter, 2002; Fischer & Whitehead, 1974; Carpenter & Niem, 1998-2001; Fischer et al., 1984) and other publications (Blackwelder, 1967), usually organized either in the form of comparative tables or dichotomous keys and supplemented with illustrations or photographs (Becker 1983). Further, limitations on publication cost and size resulted that typically only few images are available for each fish species and physical characteristics are described in abbreviated and technical language. Although this approach allows for the presentation of a large amount of information in a small amount of space, it can be intimidating and confusing, especially to the non-specialist (Jenkins and Burkhead 1994). Most importantly, the printed identification keys often lead to make few wrong decisions and it is not easy to go to the previous selection when someone is deadlocked. In case of too many selections, it leads to confusion for the reader. Also, it must be mentioned the case where new dichotomous keys must be created and printed which will be used to identify new organisms (fish species) that will appear in the area in the future (Kostoglou et al., 2012). Over the past few decades the teaching and funding of taxonomy has been declined and the revolutionary approaches to taxonomy using computer, internet, database technology and DNA are now being contemplated (Mallet, J. & Willmott, K. 2003). The recent advances in computer technology allow for development of exciting new ways to organize and present the information necessary to identify species (Stevenson et al. 2003). It also creates new challenges in database usage and information retrieval, especially where taxonomists do not provide precise rules for such systems. As taxonomists rarely rely on computer based identification and recognition technique to identify species, it is now practical to show rather than merely describe what distinguishes species. Thus, automated species identification using the taxonomic digital keys can be a better option to reduce the burden of routine fish specimen identification. However, digital keys for fish identification have been developed in recent years. Some examples of identification keys in World Wide Web are in Fish Base (Froese and Pauly, 2013), Marine Species Identification Portal (http://species-identification.org/), the Fish Identification Site (http://svrsh2.kahaku.go.jp/fishis/) helps to identify fishes utilizing countable characters such as numbers of fin rays, scales, pores, gill rakers, body rings, and vertebrae. All these identification systems are web applications and uploaded as web pages into a website. Thus, the advancement and boom in digital technology have provided opportunities to address the task of identification by developing several keys of this type in order to facilitate ichthyologists, researchers or students that need. All fish identification digital keys are based on printed keys and no new keys have been created so far (Kostoglou et al., 2012). Technically speaking, two types of digital

keys were seen. First, the more simple digital keys with static content developed with HTML covering a set of information (data on fish species, fish images and all the necessary information which compose a fish identification key), which is stored and divided into a number of pages. These pages compose a webpage. Second the more complex digital keys developed under both HTML and a scripting language (either PHP (Hypertext Pre Processor) or ASP (Active Server Pages)). The former simple digital key is not flexible due to improper organization and lack of updating capabilities. On the other hand, the more complex digital keys are dynamic content web pages ensuring that all the necessary digital key information for the operation is being stored into a database and thus, possess updating capabilities. This type of system allows the user to makes a selection every time and recovers the set of information from the database, which is shown to the user through the browser. An extensive review of literature on the existing fish identification digital keys revealed that there are no fish identification systems providing complete and correct update capability on digital keys. The information system that has been developed in the present work constitutes the first fish identification system using database approach for the digital keys of the fish species reported from the origins of India. In view of this, a web framework was designed and implemented using SQL Server 2008 relational database management system, ASP.NET and C# language to identify and describe the fish specimen of the post larval life stages. The distinguishing characters from morphometric measurements and meristic counts were used as taxonomic key characters. The principal objectives included in this study were to (a) prepare the digital keys for distinguishing characters aid in identification (b) developing the morpho-meristic database (c) develop the pathway for identification and automate the identification process by developing a web application framework integrated with database (d) share and make it freely available to the users through Internet (d) develop the digital registration of fish species. The designed system is fully interactive with the user and can be used remotely via the World Wide Web. The information system provides an easy and user-friendly environment which gives the user multifaceted fish identification capabilities and a fast search function for all included fish species. Furthermore, its innovative additional function shows information on other characters like maximum size, common name, synonyms and distribution.

MATERIALS AND METHODS

Data Source

The published secondary sources like handbooks, journals, conference proceedings, online databases and offline databases were used for collecting data on the distinguishing taxonomic characters aiding in the identification. The collected data on these characters were documented on the standard digital datasheet grouped under features like body, fins, scales, scutes, head, gills, mouth, eyes, colour and chin as described in **Table 1**. Data on other characters like maximum size, common name, synonyms and distribution about each fish species were also collected and documented. In this way, data for a total of 220 fish species belonging to 12 families were collected.

Database Development

The INDfishTaxonomy_DB database was developed using the SQL Server 2008 enterprise edition to manage the data. SQL Server 2008 works at the backend and provides command to retrieve and store data into the database. **Figure 1 shows** the architecture of the database. The dbo.fishprofile table contains the entry for characters as shown in **Figure 2** and **Figure 3**. fishid is a primary key field of this table.

Interface and Application

The web version interface of the identification system was developed as ASP.NET website using Microsoft's ASP.NET and C# programming language. Microsoft's ASP.NET of Visual Studio 2008 and C# programming language was used to build the ASP. NET web site and web pages. The web pages provide interface and functions to fetch and display data from the database. At present, the system runs on server class Intel machine under Microsoft's 2008 server operating system. The combination of ASP.NET, C# and SQL Server 2008 is efficient, much easier and powerful for database management under windows environment.

RESULTS

IND fishTaxonomy_DB database covers entries about 220 fish species reported from Indian origins as shown in **Table2**. A fish registration option implemented with checks and validation rules provides the facility for registering the data into the database. The various tools as utility tools were developed and integrated with web interface to facilitate the user to work with the database.

Utility Tools

For the identification, retrieval and storage of data into the database various tools like search, browsing and registration in the home page of the website were integrated as depicted in **Figure 4**. 'Search' and 'SEARCH FISH 'are search tools. 'FISH REGISTRATION' is a tool for registering and storing the information about fish species of interest into the database. 'FISH DETAILS' is a browsing tool to browse the information on fish species of interest from the database. Additionally, hyperlinks to other websites were also provided.

Keyword Search

This is a simple text search tool which has been provided for searching information based on the keyword typed by the user and retrieve the information. This search only works with the 'scientific name' of the fish which has to be typed in the text box area provided against to 'Search' in the home page of the web site. The click event from the mouse on the 'Search' button provides the result of search. **Figure 5** shows the sample screen print of the keyword typed by the user into the text box area against to 'Search'. **Figure 6** shows the sample screen view after search.

Fish Species Identification

The 'SEARCH FISH 'tool identifies the fish species from the database based on the values keyed in. The tool opens a form before the user for keying in or select value/ values. In the form, some fields are mandatory in requiring values. **Figure 7** shows the sample screen view of the data entry sheet for identification and **Figure 8** shows the sample screen view of the result after entering sample values.

Browsing Fish Details

'FISH DETAILS' is a browsing tool that displays the page wise information on all fields or selected fields about all fish species. **Figure 9** shows the sample screen view after browsing.

Registration and Storing the Information on Fish Species

'FISH REGISTRATION' is a tool in the web interface to register and store the information about fish species in the transaction table of the master database INDfishTaxonomy_DB. The tool opens a form for keying in the data. This tool

in the web interface was included to provide security to the database and convenience to the user to register the information about the fish species. **Figure 10** shows the sample screen view of the form for registering and storing the information.

DISCUSSIONS

An essential prerequisite of any broad based programme of resource management is proper identification of the potential species in the awake of several natural and anthropogenic threats. Computers have provided virtual labs to the researchers and thereby gaining the importance day to day. They are more effective means of aid for identification when used interactively. Many computer based identification system exists for identifying fish species using either of the approaches of data matrix, rule based expert systems and frame based expert systems. Each approach has advantage over others. These approaches further employ the different techniques and methods to classify the biological organism. The identification system developed using the rule based database approach is much interactive to the users through web components and can very well used in the field for identification of specimen with some accuracy. The development of such identification system will help the fish taxonomists and conservation biologists for managing the fish species of interest. The utility of the system lies in applying the digital technique using external characters of fish specimen for identification. The system offers advantages in (1) resolving taxonomy ambiguities (2) quickly and easily identify the fish species in the field (3) taking up the fish species of interest for further studies. However, the system presently contains identification information limited to few fish species found in India, however it provides approach for implementing alternative method for identification using digital technologies. The results obtained from the database will also add the knowledge for assessing, managing and conserving fish biodiversity. Advances in the statistical and machine learning techniques has opened several new tools like Support Vector Machine(SVM), Artificial Neural Network (ANN), Fuzzy logic, Bayesian Classifier etc to identify the fish species. The development of digital techniques using shape analysis have offered to fishery biology new possibilities of research to identify stocks by means of morphometric characters of fish or otoliths (Campana et al. 1993, Bolles et al. 2000 and Begg et al., 2001). Computer vision and image processing have also played key role for identification of the fish species using the fish otolith images (Lombarte et al. 1991, Lund et al. 1993 and Tuset et al. 2003), eye images (Hosseini et al. 2008). For the identification of some special cases of fishes with no visible eyes, such as flounders and soles, fish skin images were used instead of fish eye images. In another study, binary images taken using video camera were used to recognize the species of fish and obtained good results but had low expandability, i.e., it was difficult to increase the system's ability of recognizing new species of fish (Castignolles 1995). Acoustic-school descriptors that employ acoustic instruments use several methods for automatic species recognition and classification. A web-based resource known as the Regulatory Fish Encyclopedia (RFE) produced by US Food and Drug Administration (FDA) several years ago was used to aid in the identification of commercially important species of fish (Tenge *et al*. 1997). Organized into a series of species "pages", the RFE contains high resolution images of whole fish and their marketed product forms (*e.g*. fillets, steaks), as well as other taxonomic, geographic, and relevant tools for species identification. An example of an identification method listed in the RFE is protein identification by isoelectric focusing (AOAC 1980). Isoelectric focusing is a currently accepted tool employed in the identification of fish fillets for regulatory compliance, but such analysis requires subjective interpretations of gel results and the inclusion of perishable frozen tissue standards in each run. Further, the technique is not effective in the case of processed or cooked samples. The RFE was designed so that it could be expanded to include additional data and to accommodate the use of new analytical tools as they became available. In 2007, under Barcode of Life initiative programme, DNA barcode sequences were generated for 172 individual authenticated fish representing 72 species from 27 families contained in the RFE and the utility of DNA

barcoding for regulatory seafood identifications was demonstrated (Yancy *et al*. 2008a). DNA sequencing of the cytochrome c oxidase subunit I gene (COI) fish tissue samples for obtaining unique, species-specific "barcodes" has become the promising molecular taxonomy method for accurate fish species identification but can only complement the existing approaches of conventional taxonomy. According to Mallet and Willmott (2003) "DNA barcodes based on a few specific genes may fail to distinguish closely related species because of the persistence of ancestral polymorphism". It is also feared that DNA barcoding exercises may supplant genuine taxonomic projects and merely end up in spewing-out alternate sets of data, without adding meaningful information on the taxa (Ebach and Holdrege 2005). Additionally FishBase, an online compendium of world fishes includes the tools for identification of fish species using taxonomic keys, morpho-metric measurements and images of the fish species. The database has been integrated with identification tools to identify the fish species of different countries. In this database, few morpho-meristic features have been considered for identification. IPez, an expert system for the taxonomic identification of fishes based on machine learning technique was developed using the morphometric characters in more than 8900 individuals belonging to 6 classes, 43 orders, 192 families, 510 genera and 847 marine and freshwater species (Guisandae C. et. al. 2010). This system aims to determine the taxonomic identification of juveniles and adult fishes is possible using these measurements.

Thus, the present discussion explored several tools employing different techniques used in the fish identification. All such tools are either limited to the ecosystem, or geographic boundary or group boundary or in employed technology. At present, there is no universal automated tool in the world crossing all these boundaries to identify the fishes. Since, this identification system uses morpho-meristic characters for identification, it is understood that the system is scalable and even can be more reliable and relied by the taxonomists.

CONCLUSIONS

This study shows that the web framework for identifying post larval stages of fishes is an alternative approach, which can serve as a model for fishes of other countries. It includes fish identification capability through searches dived into multiple steps. The fish species can be searched either by searching by the species name, or by applying the taxonomic selection procedure. The navigation function, which is being enabled every time a user is trying to identify a species, is a strong and useful advantage. The system has presently identification records for 220 fish species so far, however the hypothesis cannot be rejected if in the future the identification fails as the number of species increases because the species are identified systematically based on taxonomic digital key characters. The system is complex with web version, and required substantial time and effort to develop. The aim of developing the automated identification system was to reduce the time spent in taxonomic identification of fishes and provide a tool for minimizing errors in identification. Further, collection of data on distinguishing key characters was much difficult and time consuming. Identification of taxonomists and getting their opinion to develop the path for identification was rather much difficult as taxonomists are very few in India.

LIMITATIONS AND FUTURE PROSPECTS

The major limitation in developing the web version of the identification system was the collection of information on distinguishing key characters targeting identification as it was found too overlapping, scattered and also limited to old publication and sometimes not available/ or out of print. Therefore, extensive literature search and taxonomist's input is required to further expand and increase the identification performance of the system. In future, the system would be

expanded by including the information on identification for the remaining fish species of our country. Beside, data on the other parameters like ecology, life history, biology and breeding would also be added to increase the scope and content of the database. Additionally there is need to update the database by including more parameters of the systematics.

AVAILABILITY AND REQUIREMENT

Our web version of fish identification software can be accessed at URL http://www.nbfgr.res.in/ASIS. To access it, World Wide Web is a prerequisite.

ACKNOWLEDGEMENTS

The authors are grateful to the Director, National Bureau of Fish Genetic Resources, Lucknow for providing the necessary facilities for the project.

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APPENDICES

Table 1: List of Key Characters for Identification under Morphometric and Meristic

Features	Taxonomic Characters for Identification
Body	Body type, Belly, Body depth, Head shape, Snout shape, Origin of Dorsal fins
Fins	Dorsal Fin: Presence, Peculiarity, Position, Number of spiny and soft rays
	Pectoral Fin: Presence, Peculiarity, Position, Number of spiny and soft rays
	Ventral Fin : Presence, Position, Peculiarity, Number of spiny and soft rays
	Anal Fin: Presence, Position, Peculiarity, Number of spiny and soft rays
	Caudal fins type, Color, Caudal peuncle types, Number of finlets
Scales	Scale type, Présence of Auxiliary scales and type, Scale arrangement, Scale count
Scutes	Presence of scutes, Scutes counts, Scutes Shape
Head	Shape of head, Head profile, Opercle type, Prepercle type, Number of opercle spines, Number of prepercle spines, Type of Interobitul space in relation to snout length
Gills	Gill opening, Gill rakers count, Number of Branchiostegal Rays, Number of Pseudobranchiostegal Rays
Mouth	Type, Jaws, Snout shape, Teeth (type and size), Eyes (position and pecularity of Eyes)
Colur	General Colour, Peculiarity in Colour
Chin	Barbels (size, position, numbers), Pores (numbers, position)

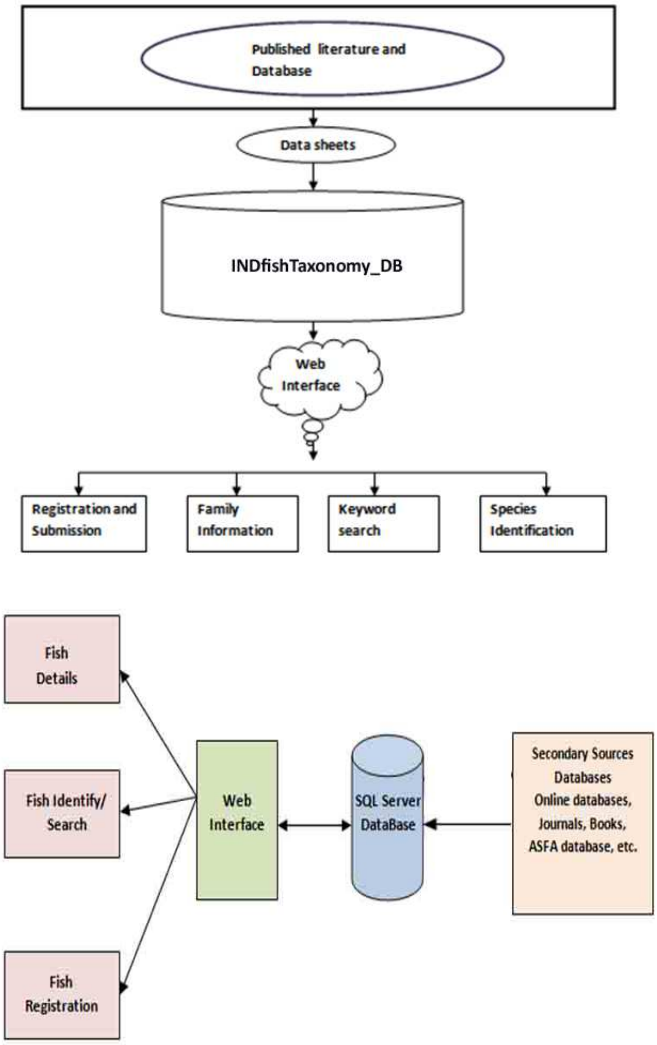


Figure 1: Architecture of the Database and Flow of Data from Database

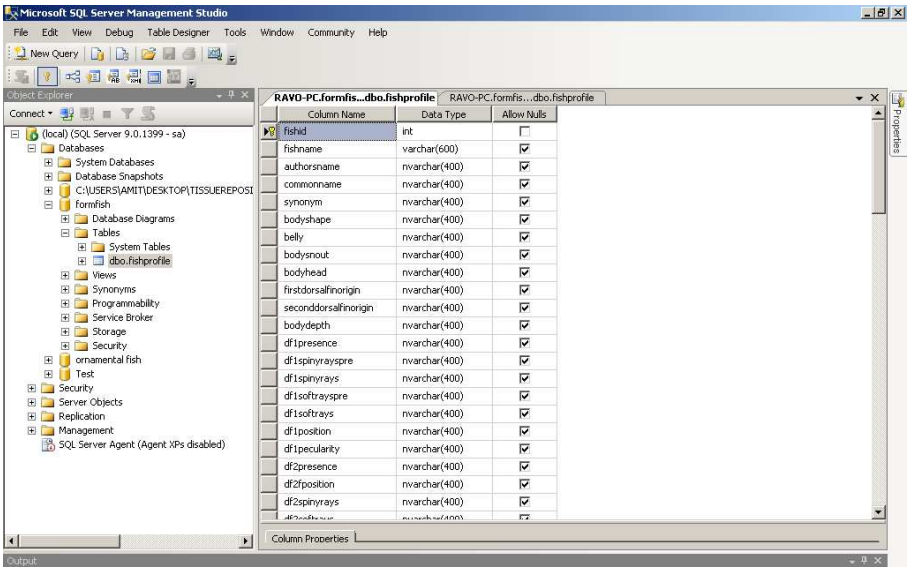


Figure 2: Sample Screen Print View of the Tables and their Attributes covered in the Database

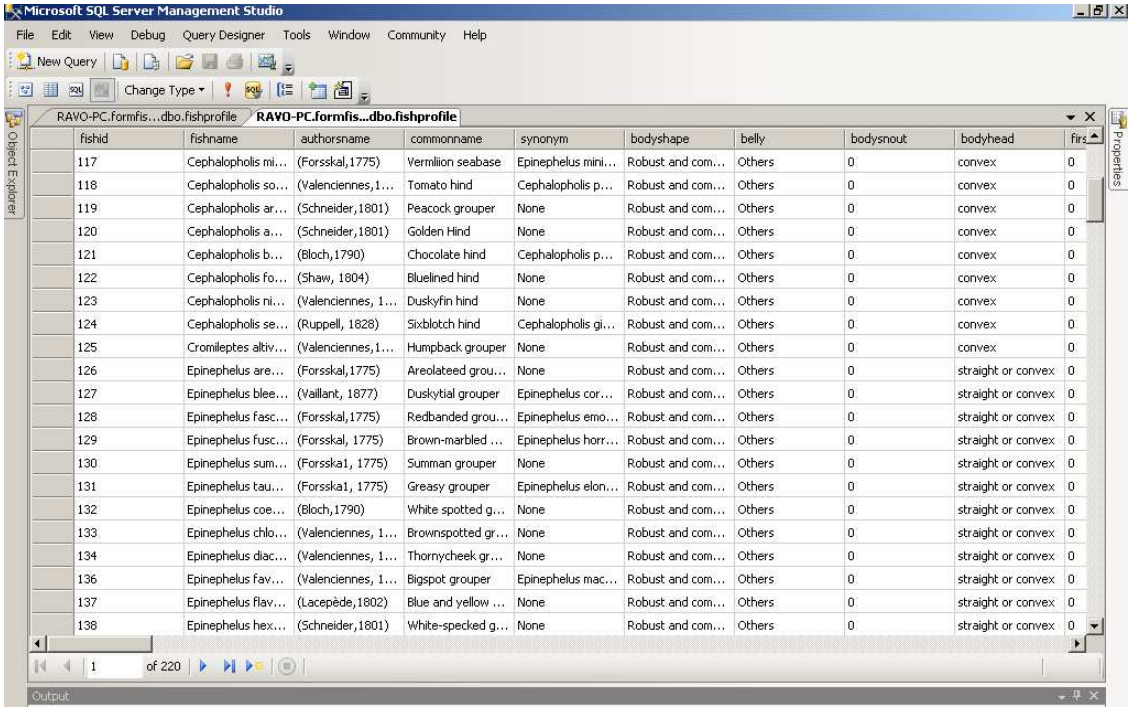


Figure 3: Screen Print View of Values covered by the Attributes of the Database

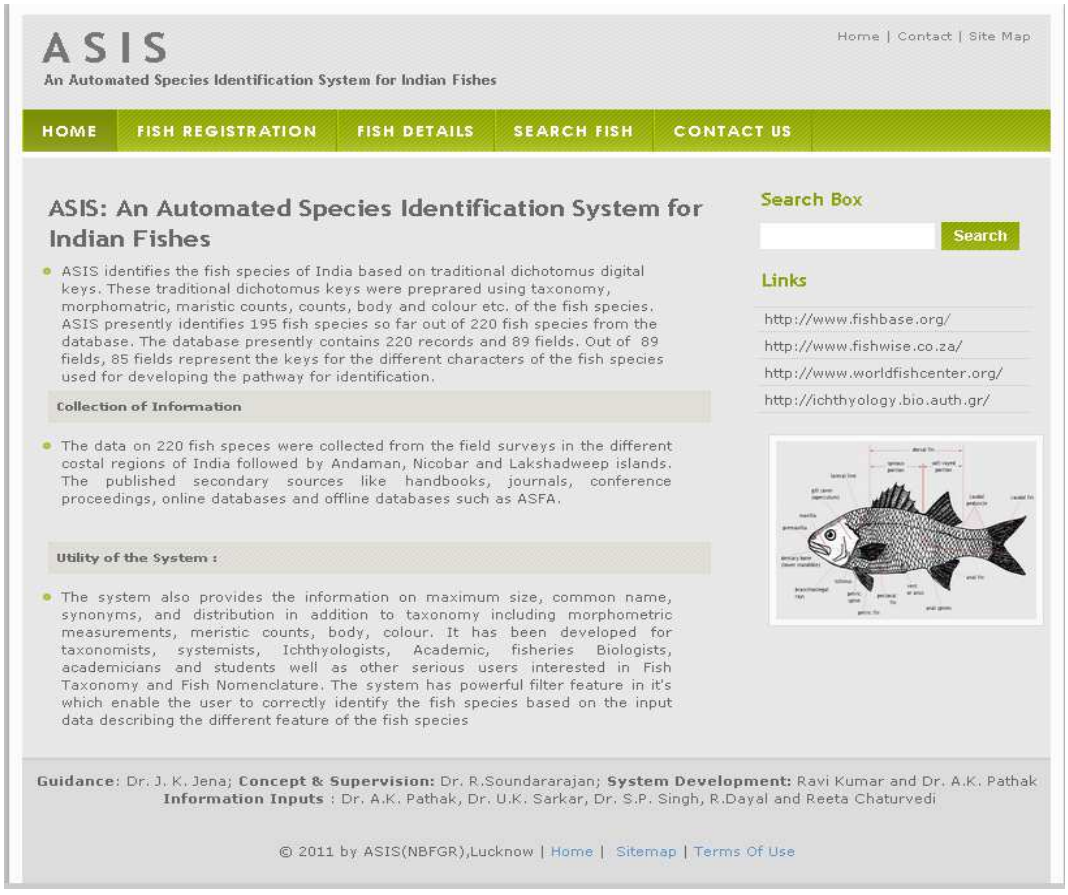


Figure 4: Sample Screen Print View of the Web Interface of and Identification System

Figure 5: Sample Screen View of the Keyword Typed by the User Against to 'Search'

Fish Details	
Fish Id:	122
Fish name :	Cephalopholis formosa
Authors Name :	(Shaw, 1804)
Common Name :	Bluelined hind
Synonym :	None
Body Shape :	Robust and compressed
Belly :	Others
Fins Description	
Dorsal fin Ray :	17
Dorsal fin position :	0
Dorsal fin peculiarity :	0
Ventral fin ray :	5
Ventral fin position:	0
Anal fin ray :	8
Anal fin position :	0
Scales Description	
Scale arrangement :	None
Scale auxiliary :	Absent
Scale lateral line :	68
Scale tr :	22
Scutes count :	0
Scute shape :	Others
Gills Description	

Figure 6: Sample Screen Print View of the Result of the Search

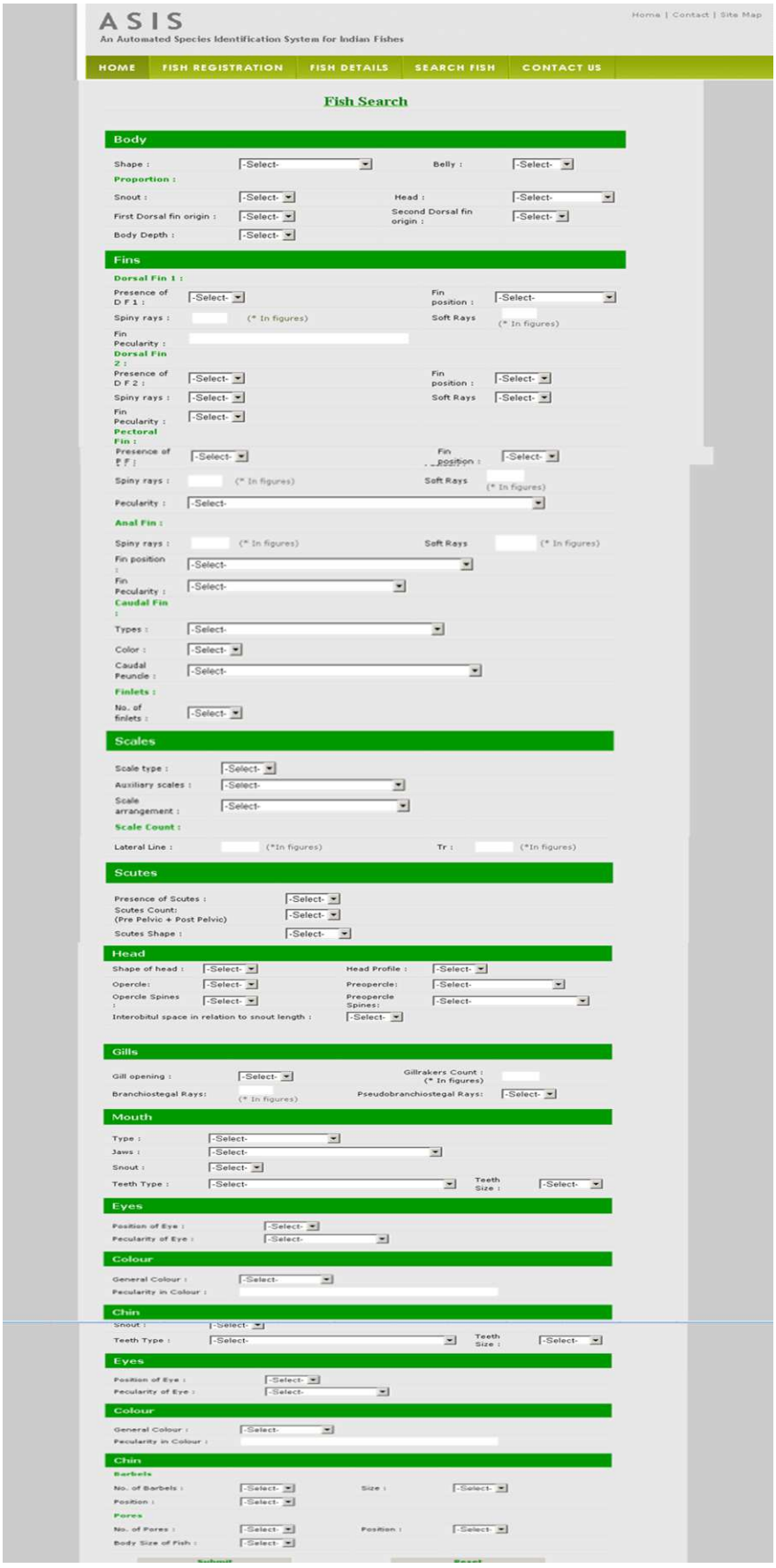


Figure 7: Sample Screen View of the Data Entry Sheet for Identification of Fish Specimen

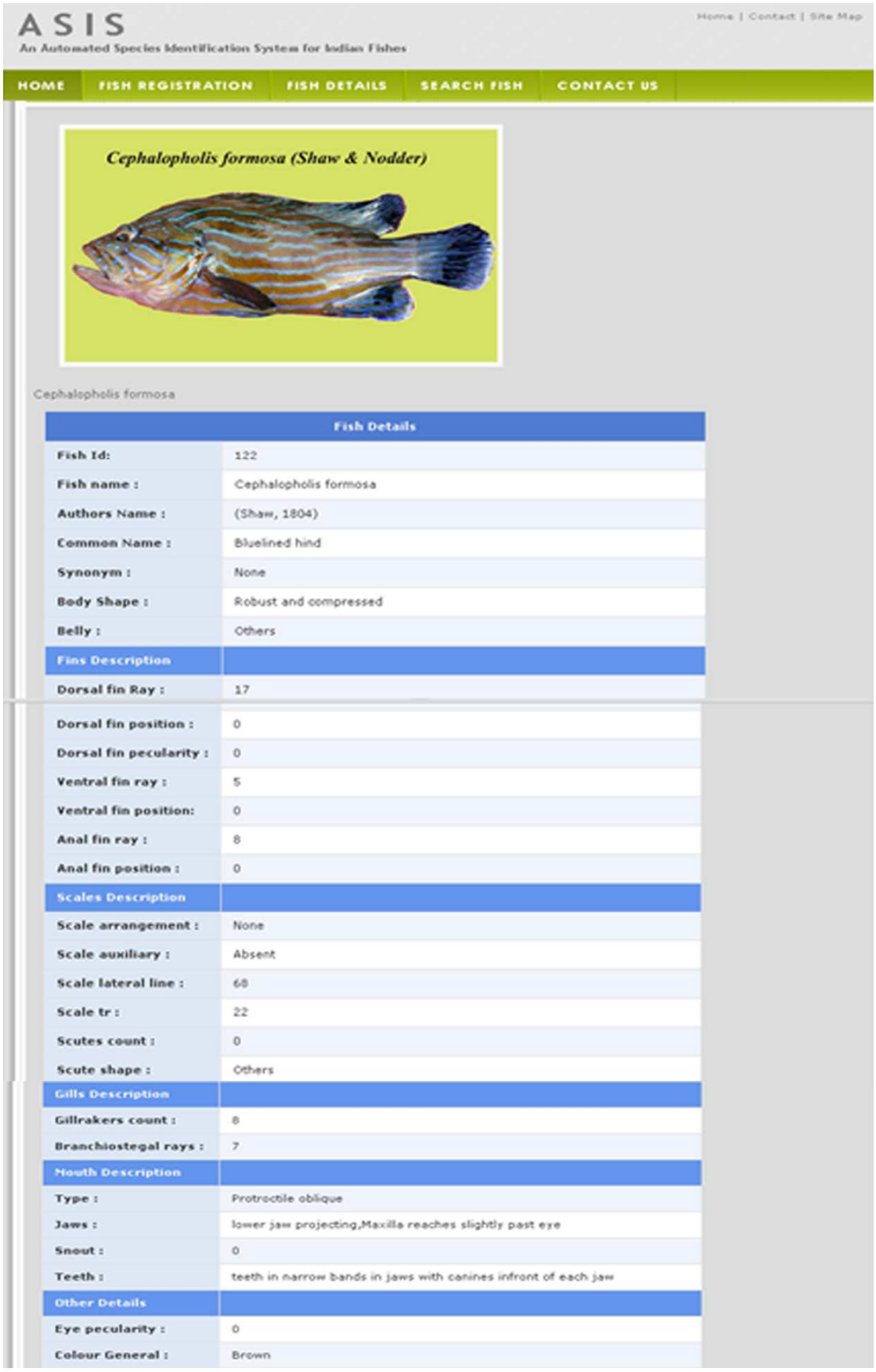
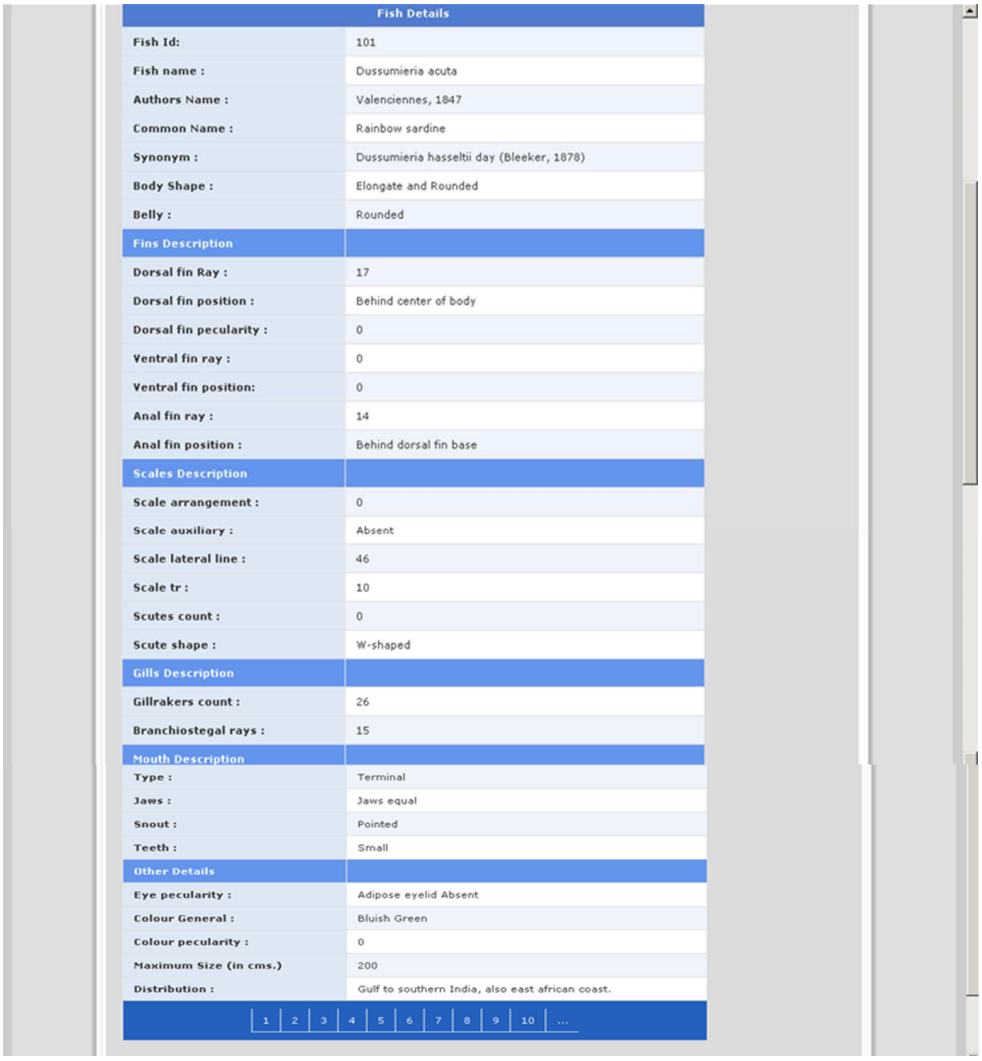


Figure 8: Sample Screen View of the Result after Query for Identification of Fish Specimen



Fish Details	
Fish Id:	101
Fish name :	Dussumieria acuta
Authors Name :	Valenciennes, 1847
Common Name :	Rainbow sardine
Synonym :	Dussumieria hasseltii day (Bleeker, 1878)
Body Shape :	Elongate and Rounded
Belly :	Rounded
Fins Description	
Dorsal fin Ray :	17
Dorsal fin position :	Behind center of body
Dorsal fin peculiarity :	0
Ventral fin ray :	0
Ventral fin position:	0
Anal fin ray :	14
Anal fin position :	Behind dorsal fin base
Scales Description	
Scale arrangement :	0
Scale auxiliary :	Absent
Scale lateral line :	46
Scale tr :	10
Scutes count :	0
Scute shape :	W-shaped
Gills Description	
Gillrakers count :	26
Branchiostegal rays :	15
Mouth Description	
Type :	Terminal
Jaws :	Jaws equal
Snout :	Pointed
Teeth :	Small
Other Details	
Eye peculiarity :	Adipose eyelid Absent
Colour General :	Bluish Green
Colour peculiarity :	0
Maximum Size (in cms.)	200
Distribution :	Gulf to southern India, also east african coast.

1 2 3 4 5 6 7 8 9 10 ...

Figure 9: Sample Screen View of Browsing the Information on Fish Species

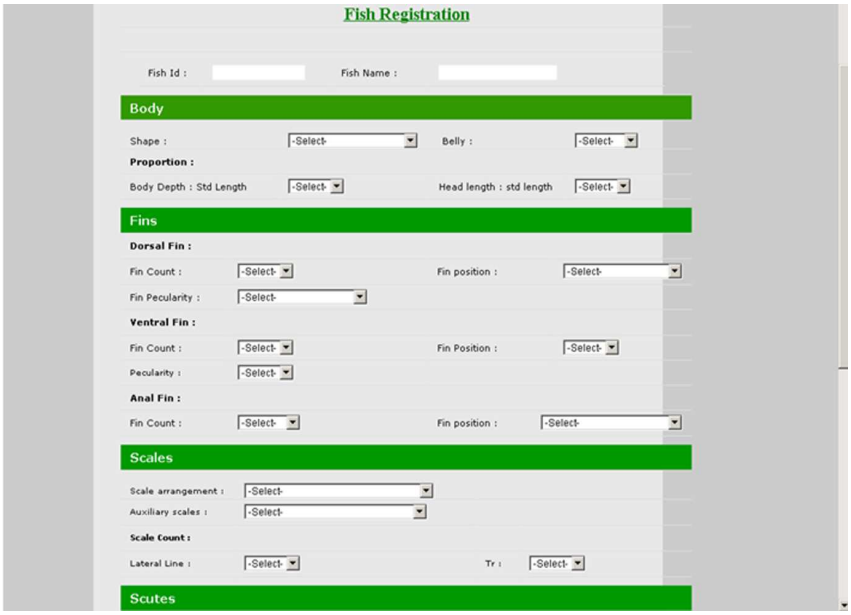


Figure 10: Sample Screen View of the Form for Registering and Storing the Information on Fish Specimen